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STANDARDIZED CATCH RATES OF ALBACORE (*THUNNUS ALALUNGA* BONNATERRE, 1788) IN THE SPANISH SURFACE LONGLINE FISHERY IN THE WESTERN MEDITERRANEAN IN THE PERIOD 2009-2019

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SUMMARY

*Standardized relative abundance indices of albacore (*Thunnus alalunga *Bonnaterre, 1788) caught by the Spanish surface longline (LLALB) in the western Mediterranean Sea were estimated for the period 2009-2019. Yearly standardized CPUE were estimated through Generalized Linear Mixed Effects Models (GLMM) under a negative binomial error distribution assumption. The main factors in the standardization analysis were year and season (quarter). The index shows an increasing trend from the beginning of the series (2009) to a maximum in 2011; following a decrease up to 2013, and a relatively stable trend fluctuating around a level three and a half times lower compared to the maximum abundance for the period 2013-2019.*

RÉSUMÉ

*Les indices d'abondance relative standardisés du germon (*Thunnus alalunga, *Bonnaterre, 1788) capturé par la pêcherie palangrière espagnole de surface (LLALB) en Méditerranée occidentale ont été estimés pour la période 2009-2019. Les CPUE standardisées annuelles ont été estimées par le biais de modèles linéaires généralisés avec effets mixtes (GLMM) en postulant une distribution d'erreur binomiale négative. Les principaux facteurs de l'analyse de standardisation étaient l'année et la saison (trimestre). L'indice présente une tendance à la hausse au début de la série (2009) pour atteindre un maximum en 2011, suivi d'un recul jusqu'en 2013 et d'une tendance relativement stable fluctuant autour d'un niveau de trois fois et demi inférieur à celui de l'abondance maximale de la période 2013-2019.*

RESUMEN

*Se estandarizaron los datos de captura y esfuerzo del atún blanco (*Thunnus alalunga*) para la pesquería atunera de palangre de aguas distantes de Taipei Chino en el océano Atlántico norte utilizando un modelo lineal generalizado (GLM). En la estandarización de la CPUE (captura por unidad de esfuerzo) del atún blanco se consideró todo un período de 1981 a 2018, lo que potencialmente tiene en cuenta la cuestión del cambio histórico de especie objetivo en esta pesquería. La CPUE estandarizada del atún blanco desarrollada por periodo mostraba tendencias casi idénticas a las derivadas del modelo de todo el periodo. Sugerimos el uso de este índice para 1981-2018 dada la mejora del modelo. En general, la CPUE estandarizada del atún blanco en el océano Atlántico norte comenzó a disminuir levemente a principios de la década de 1980, pero mostró un pico relativo en 1997 y luego volvió a disminuir. La tendencia siguió siendo al alza desde finales de la década de 1990 hasta 2014, y luego disminuyó ligeramente en los cinco últimos años, de 2014 a 2018.*

KEYWORDS

Albacore, Longline, Stock assessment, Catch/effort, Pelagic fisheries, Mediterranean Sea

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1. Introduction

1.1 Description of the fishery

The Spanish longline fishery targets albacore (Thunnus alalunga) in the western Mediterranean by using a drift longline (LLALB) in high-sea fishing grounds at depths up to 1500 m **(Figure 1)**. Between 2000 and 4000 hooks are deployed by fishing operation (set) with hook depth ranging from 20 m to 50 m. Normally a daily set per fishing day is made. The most commonly used bait is sardine (*Sardina pilchardus*) and round sardinella (*Sardinella aurita*). Although active throughout the year, the main fishing season lasts from May to September. The fishery is characterized by its strongly artisanal nature, and has remained fairly stable since its inception in the late nineties. As is the case for the main fisheries in the western Mediterranean, the LLALB fishery is scientifically monitored by both the Spanish Institute of Oceanography (IEO) Information and Sampling Network, and the IEO On-Board Observer Program.

1.2 Regulation measures in force

Until 2017, with the exception of some domestic technical specifications related to the characteristics of the fishing gear (number of hooks, hook size, main line material and main line length,), the Mediterranean albacore fishery was not subjected to any regulation measure.

From 2017 onwards, ICCAT's Mediterranean swordfish rebuilding plan prescribed a closure period, aiming at protecting swordfish juveniles, from the 1 October to 30 November each year, to the longline vessels targeting albacore in the Mediterranean Sea (ICCAT Rec [16-05;12]).

In addition, all Contracting Parties and Cooperating Non-Contracting Parties (CPCs) shall provide to the ICCAT Secretariat the list of all catching vessels authorized to fish actively for Mediterranean albacore tuna (ICCAT Rec [16-05;28]).

2. Material and methods

Data for the analysis was collected from the Spanish pelagic longline fishery targeting albacore in the western Mediterranean. The information, recorded on a trip basis, included: vessel identification, date and geographical location (area 5x5) by fishing operation (set), fishing effort (number of hooks), catch (either biomass in kg or number of fish) and, whenever possible, the length composition of the catch.

2.1 Data exclusions

Data inspection basically entailed the elimination of incomplete and erroneus records, such as incorrectly recorded number of fish weight or fishing effort. Whenever possible, incorrect measurement units were corrected. As a result, approximately one per cent (1%) of the records available for the period 2009-2019 was eliminated for later analysis.

2.2 Analytical approach

An exploratory analysis (results not shown in the document) of the available data based on a Poisson error distribution pointed to the existence of overdispersion. Thus, indices of abundance were estimated by a generalized linear modeling approach assuming a negative binomial model (NB). For a response variable recording catch in number of fish, the negative binomial distribution, like the Poisson distribution, describes the probabilities of the occurrence of numbers greater than or equal to 0. Unlike the Poisson distribution, the variance and the mean are not equivalent. The variance of a negative binomial distribution is a function of its mean and has an additional parameter, the dispersion parameter, θ or k, which might serve as a proper approach for modeling counts with variability different from its mean.

The NB generalized linear mixed model (GLMM) was parameterized as a rate model in which the fishing effort (number of hooks) was implemented as an offset, which reflects the total effort by set over which the count response (number of fish) was generated. In fact, the offset is an exposure variable with a coefficient constrained to a value of 1.0 (i.e., enters into the model as a constant). Since the natural log ($\log_e$) is the canonical link for the NB model, the offset was logged prior to entry into the estimating algorithm. A priori explanatory factors in the model were year, area and quarter. The relevance of individual factors and the interactions between them was assessed by means of a stepwise regression procedure. The criterion used to determine the set of factors and interactions that significantly contributed to the explanation of the variability observed in the data implied the assumption that the difference in residual deviance (essentially a measure of the variability explained by the model) between two consecutive models follows a Chi-square distribution ($\chi 2$) with degrees of freedom equal to the difference in number of parameters estimated in both models (McCullagh and Nelder, 1989).

The analyses were conducted and the graphs designed using R statistical software (R Core Team, 2017). Among others, packages MASS (Venables and Ripley, 2002), glmmTMB (Brooks *et al*., 2017), emmeans (Lenth, 2018), DHARMa (Hartig, 2019) and ggplot2 (Wickham, 2016) were of particular help.

2.3 Model specification

The GLMM NB final model was defined as:

number ~ year + quarter + offset(log(effort)) + (1|year:quarter)

3. Results and Discussion

Fishing ground for the Spanish longline fishery targeting albacore is shown in **Figure 1.**

A total of 262 fishing sets for the period 2009-2019 were available for analysis. An annual summary of the information available for the analysis (number of sets, fishing effort, nominal catch in number and weight and corresponding nominal catch rates) is given in **Table 1.**

Figure 2 shows the distribution of factors (month, quarter and area) used in the standardization analysis. Treatment combinations across years were quite unbalanced.

Table 2 report type-II and type-III analysis-of-variance results for the final GLMM-NB model.

Factors year and quarter, and the year: quarter interaction were statistically significant (α =0.01). To obtain estimates of an annual index, the interaction year: quarter was included as a random effect in the final model.

Figure 3 and **Figure 4** show residual diagnostics for assessing the final NB-GLMM model fit. Q-Q plot (residuals uniformity) very close to linear. A formal test (K-S), not statistically significant. Dispersion plot and corresponding test indicates no evidence of dispersion (either over or under). Plots of the standardized quantile residuals against the explanatory variables in the model were quite flat: no identifiable patterns. Plots of the standardized quantile residuals against the explanatory variables not in the model quite flat: no identifiable patterns Even though the residual patterns show some departures from distributional assumptions at the tails, generally adequate fit the model.

Table 3 records estimated standardized relative abundance indices, standard errors and corresponding 95% confidence limits for the NB-GLMM model (linear scale). **Figure 5** shows estimated standardized relative abundance indices for model NB-GLMM.

The index shows an increasing trend from the beginning of the series (2009) to a maximum in 2011; following a decrease up to 2013, and a relatively stable trend fluctuating around a level three and a half times lower (compared to the maximum abundance) for the period 2013-2017.

References

Brooks, M., Kristensen, K., van Benthem, K., Magnusson, A., Berg, C., Nielsen, A., Skaug, H., Maechler, M., Bolker, B., 2017. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling, The R Journal 9 (2), 378–400.

Hartig, F., 2019. DHARMa: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models, URL https://CRAN.R-project.org/package=DHARMa. R package version 0.2.4.

Lenth, R., 2018. emmeans: Estimated Marginal Means, aka Least-Squares Means. R package version 1.3.1.

Venables, W., Ripley, B., 2002. Modern Applied Statistics with S, Springer, New York, fourth edn. ISBN 0-387-95457-0.

Wickham, H., 2016. ggplot2: Elegant Graphics for Data Analysis, Springer-Verlag New York.

Table 1. Summary table. Spanish LLALB, western Mediterranean. 2009-2019.

year	*sets number*	*Catchkg*	*catch (hook 10^{-3})*	*effort*	*nominal CPUE (N hook 10^{-3})*	*nominal CPUE (kg hook 10^{-3})*
2009	26	1742	13291.99	92.80	18.77	143.23
2010	38	3559	29111.03	142.94	24.90	203.66
2011	26	1771	13518.19	69.28	25.56	195.12
2012	98	3842	33117.94	305.21	12.59	108.51
2013	47	1518	14117.51	171.11	8.87	82.50
2014	na	na	na	na	na	na
2015	3	158	1725.72	16.38	9.65	105.36
2016	1	22	219.80	3.38	6.51	65.03
2017	20	669	6276.00	53.12	12.59	118.15
2018	na	na	na	na	na	na
2019	3	70	852.12	6.76	10.36	126.05

Table 2. Type-II (top) and type-III (bottom) analysis-of-variance tables for final GLMM NB model. Spanish ALB surface longline, western Mediterranean, 2009-2019.

	Chisq	Df	Pr(>Chisq)
year	65.24	8	0.0000
quarter	24.11	1	0.0000
(Intercept)	193.63	1	0.0000
year	65.24	8	0.0000
quarter	23.85	1	0.0000

Table 3. Estimated standardized relative abundance indices (number × hook 10^{-3}), standard errors, 95% confidence limits and coefficient of variation. Spanish surface longline (LLALB), western Mediterranean, 2009-2019

year	nominal CPUE	standardized CPUE	std.err	lower.CL	upper.CL	cv
2009	18.77	14.81	2.26	10.97	20.00	0.15
2010	24.90	23.39	2.84	18.42	29.71	0.12
2011	25.56	29.22	4.33	21.82	39.13	0.15
2012	12.59	13.58	1.14	11.51	16.01	0.08
2013	8.87	8.58	0.96	6.88	10.71	0.11
2014	na	na	na	na	na	na
2015	9.65	12.58	5.51	5.31	29.80	0.44
2016	6.51	4.99	3.85	1.09	22.81	0.77
2017	12.59	12.14	2.08	8.66	17.03	0.17
2018	na	na	na	na	na	na
2019	10.36	8.70	3.91	3.60	21.06	0.45

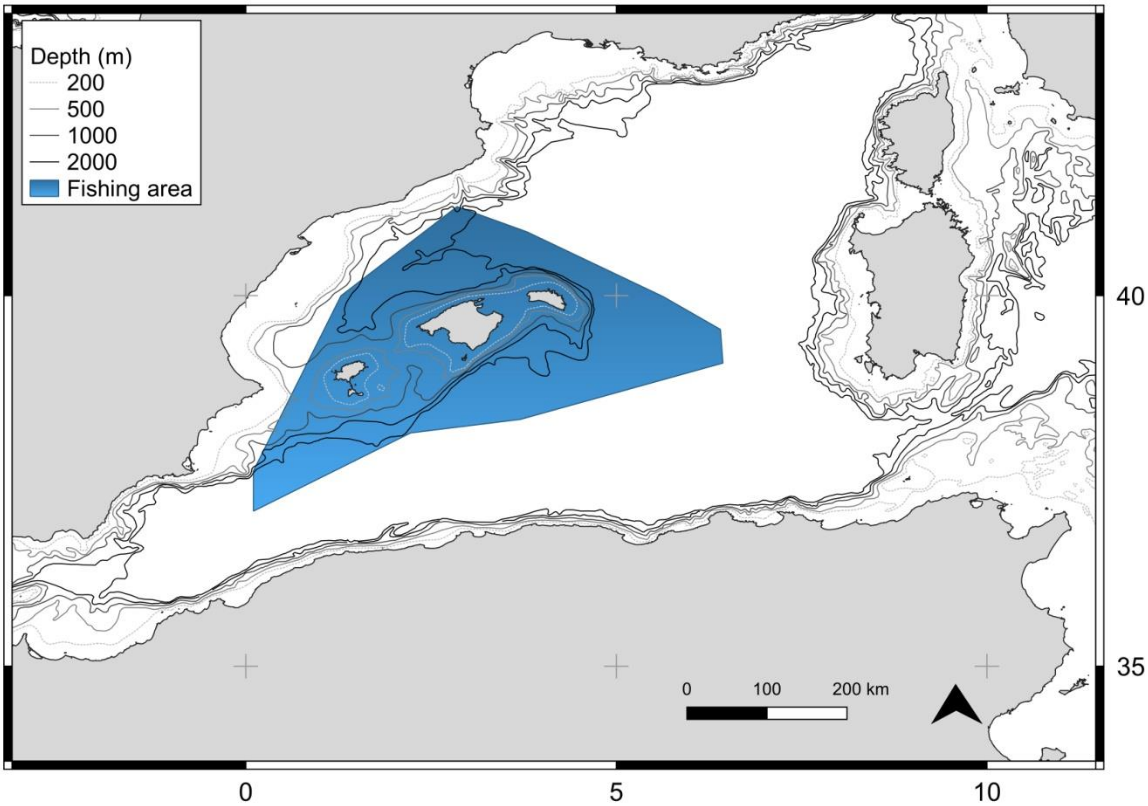

Figure 1. Spanish LLALB fishing grounds, western Mediterranean. 2009-2019.

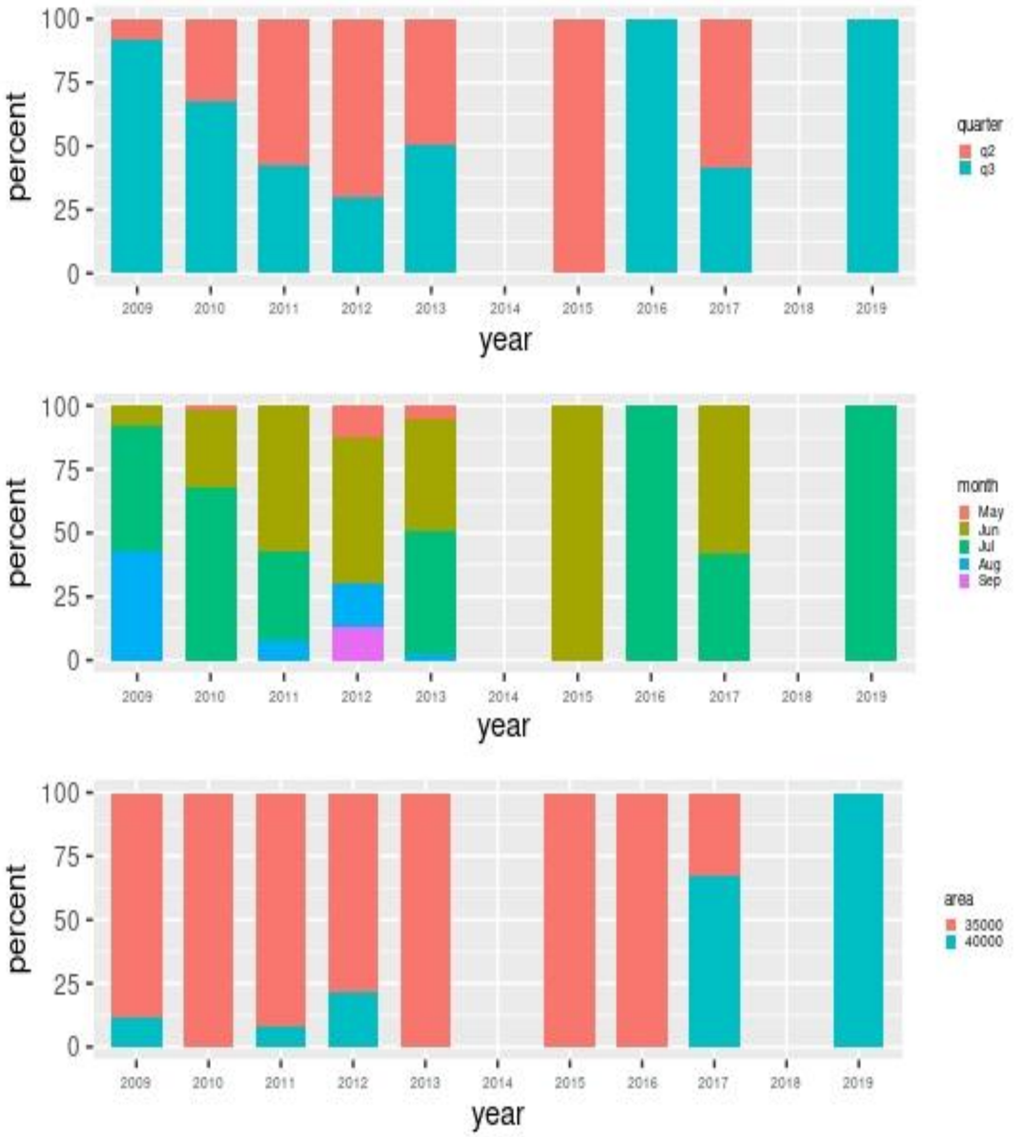

Figure 21 Temporal and spatial distribution of relevant factors in the data analyzed. Spanish LLALB surface longline, western Mediterranean, 2009-2019.

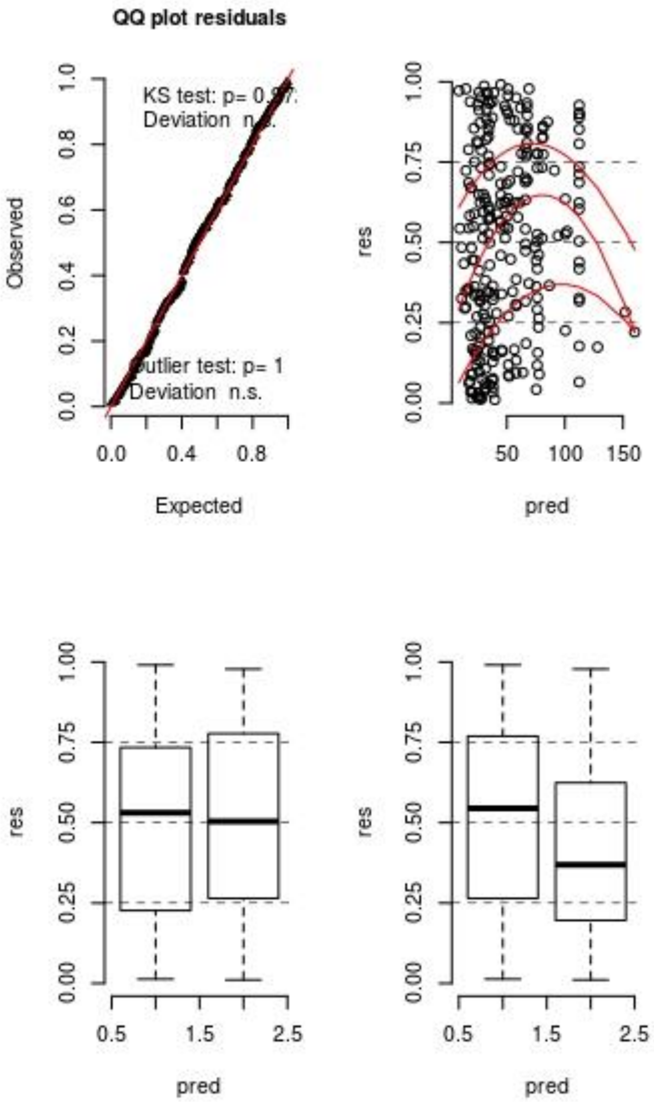

Figure 3. Residuals diagnostics (GLMM-NB). Spanish LLALB surface longline, western Mediterranean, 2009-2019.

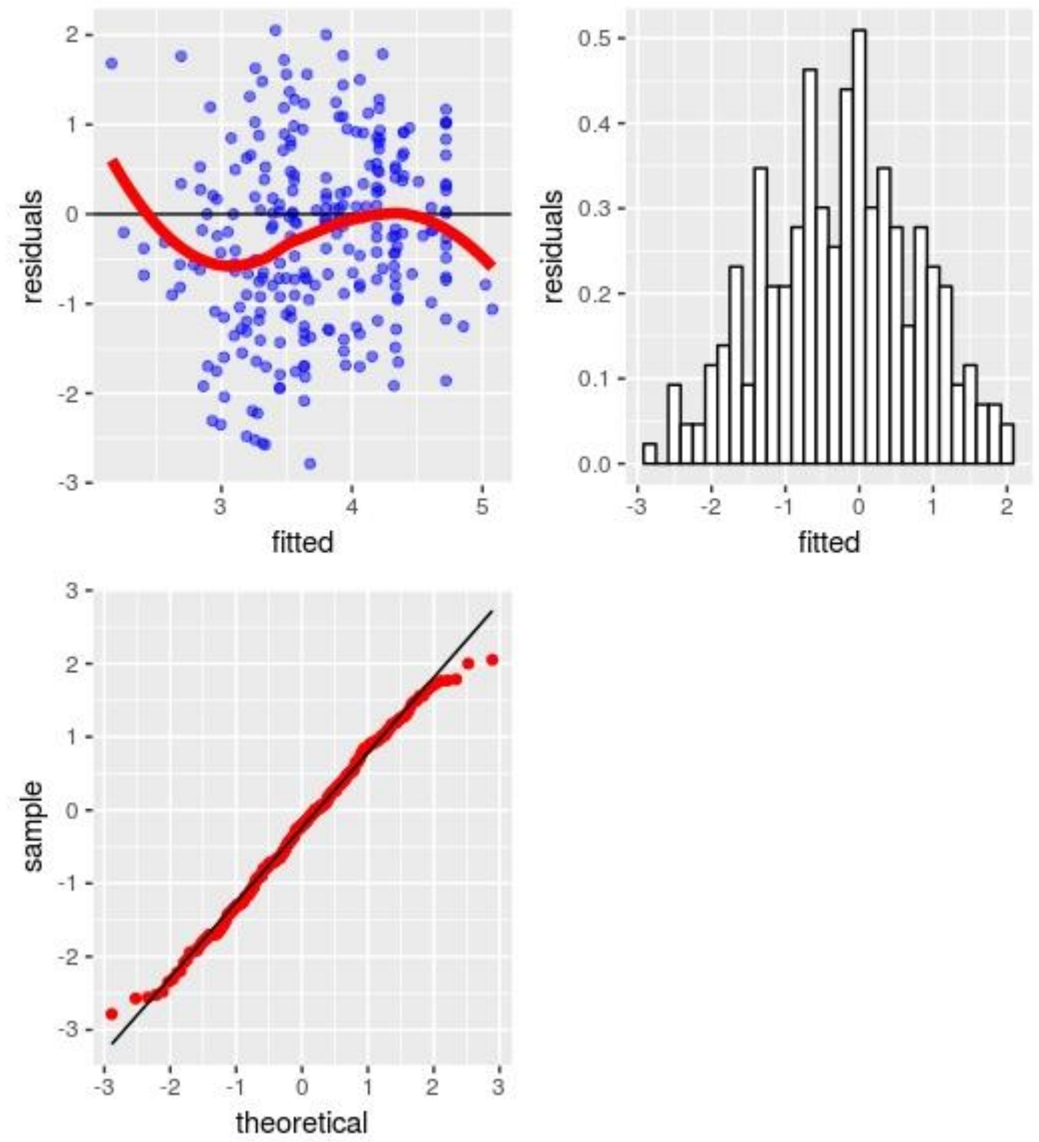

Figure 4. Residuals diagnostics (GLMM-NB). Spanish LLALB surface longline, western Mediterranean, 2009-2019.

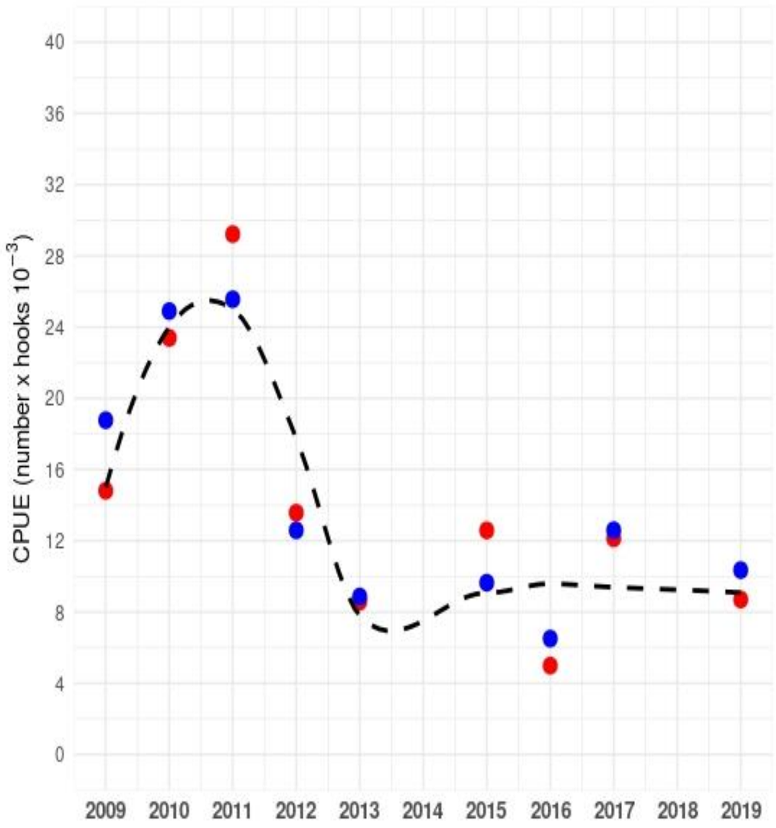

Figure 5. Standardized CPUE. 2009-2019 (red points, standardized CPUE; blue points, nominal CPUE; black dotted line, loess fit). Spanish LLALB, western Mediterranean. 2009-2019.